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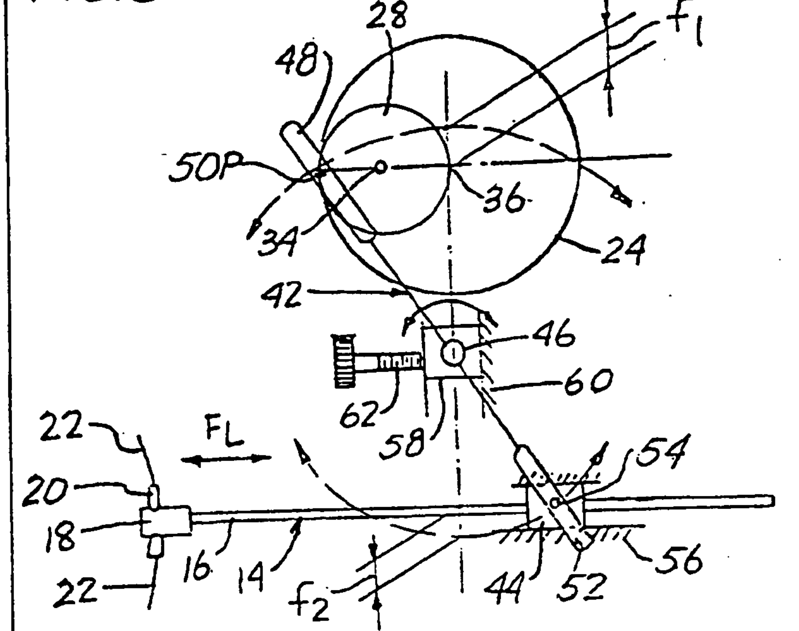
(54) Stator winding apparatus

(57) A drive for reciprocating the laying head 18 of a stator winding apparatus for electric motor stators includes a stationary ring member 24 having an inner circular track and a rotatable member 28 having a circular track engaging portion mounted for rolling movement along the inner circular track. The track engaging portion has a diameter which is substantially one-half the diameter of the inner circular track. A connecting arm 42 is provided for connecting the rotatable member to the winding element, the connecting arm being connected to the rotatable member 28 so as to be pivotable about an axis 50P in alignment with a point on the periphery of the circular track engaging portion and connected to the winding element so that the winding element is caused to reciprocate in response to rolling movement of the track engaging portion along the inner circular track. In the preferred embodiment, arm pivot 46 is adjustable during operation of the apparatus.

FIG.3



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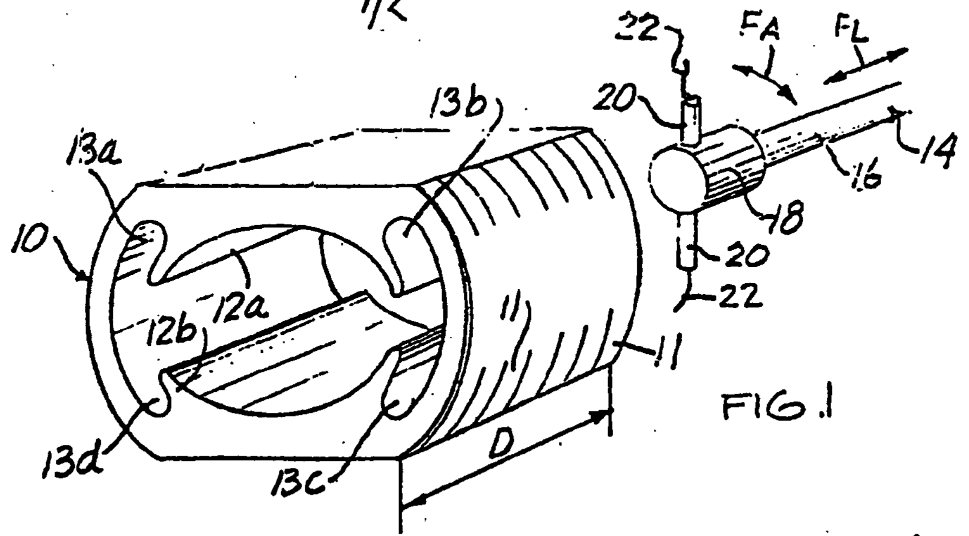

FIG.1

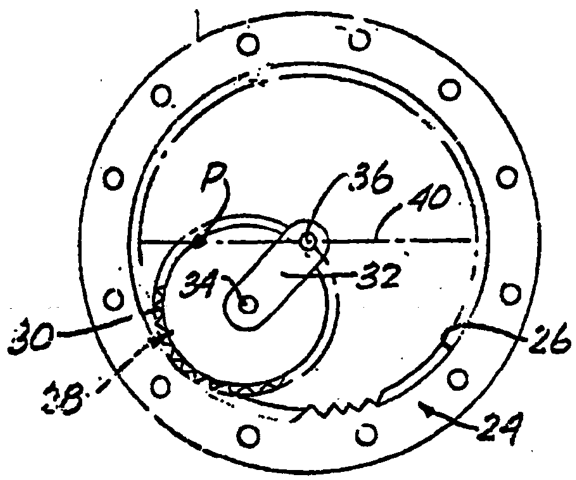

FIG.2a

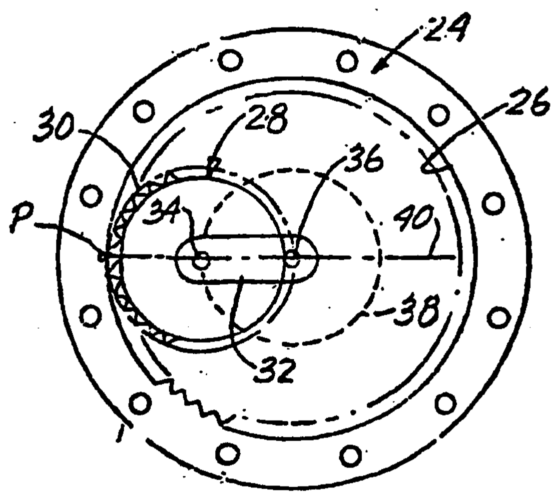

FIG.2b

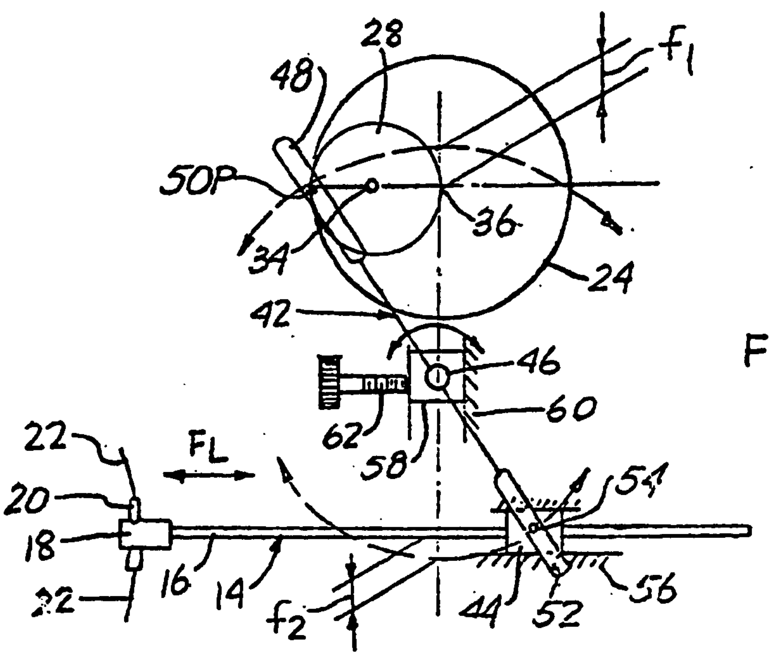

FIG.3

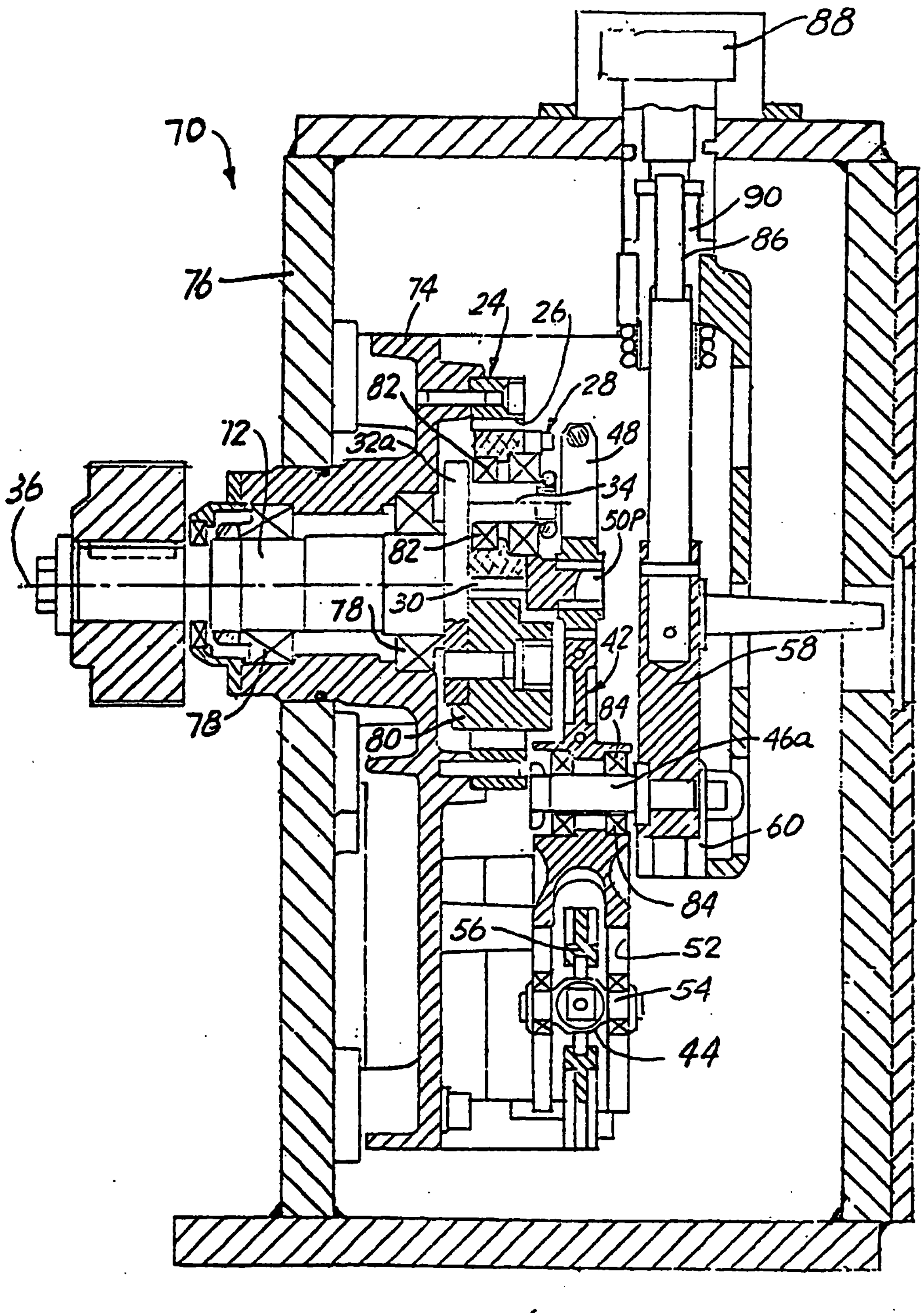
88
70
90
86
76
74
24
26
82
28
72
32a
48
36
34
82
50P
30
78
58
42
78
84
80
46a
60
84
56
52
54
44

FIG 4

SPECIFICATION

Stator winding apparatus

Field of the Invention

The present invention relates to apparatus for the formation of windings of electrical conductors in general, and more particularly to apparatus for the formation of windings on the internal field poles of stators for electric motors and other electrical machines. For example, the apparatus of the present invention is particularly useful in connection with high speed winding of stators of small bipolar electric motors.

Background of the Invention

As is generally known, stators of electric motors and other electrical machines have at least two internal field poles which extend parallel to and on opposite sides of the shaft of the motor, and on which windings of electrical conductors are to be formed. The stator element may comprise a laminate stack of core plates, the number of which may vary to thereby vary the axial dimension of the stator element. The windings of electrical conductors on each field pole are generally comprised of two straight, effectively parallel sections which run along a direction parallel to the motor shaft, and thus along the axial dimension of the laminate stack, and of two curved end loops which are formed at the ends of the laminate stack. As is also known, the formation of the windings may be accomplished by a guide element or device having a wire dispensing winding head which is moved in a generally rectangular path to wind the electrical conductors in the required pattern on the stator. This rectangular path of movement may be obtained by sequentially applying a rotary motion or oscillation and a reciprocating linear motion to the winding head.

More particularly, in presently known high speed winding apparatus, the wire guide device includes a tubular shaft having at one of its ends several small, radially distributed tubes for guiding and carrying wires destined to form the windings. A drive assembly is provided which is actuated to move the wire dispensing winding head in a generally rectangular path to wind the wire in the required pattern on the stator. Thus, the wire guide device generally possesses two combined alternative motions: an adjustable longitudinal advancement for providing the reciprocating linear motion to the winding head, and an angular movement for providing the required rotary or oscillatory motion. In this regard, as the axis or longitudinal dimension of the stator may be varied, depending upon the number of core plates which are utilized to form the laminate stack, it is desirable to provide for adjustment of the amplitude or the stroke of the longitudinal movement of the wire guide device.

In the known stator winding apparatus of the prior art, the reciprocating longitudinal movement of the wire guide device is accomplished by the connecting rod/crank device for controlling a slider element, or a crank and slotted link device. Such know systems present difficulties with regard to the adjustment of the reciprocating stroke in that the external joint of the crank must be moved, an operation which is possible only when the apparatus is rendered inoperative and which, moreover, is quite complex. Further, there are difficulties in balancing of the various components, given the high desired working rate. Still further, inconveniences and difficulties arise from the the considerable dimensions and weights utilized in question, especially in the case of crank and slotted link type systems. Additionally, the connecting rod/crank type systems do not produce a precise sinusoidally varying motion of the wire guide device, and therefore synchronism with the alternating angular motion is difficult. The crank and slotted link type of system also present difficulties or problems in terms of the working life and reliability of the slotted link due to the high speed with which the shoe slides in the transversally oriented slotted link and to the long stroke of the shoe itself.

The present invention overcomes the above noted and other disadvantages of the prior art by providing a mechanism for controlling the longitudinal reciprocating motion of the wire guide device in a highly efficient and balanced manner, and also providing the possibility of carrying out adjustments of the stroke even while the device is operating. Still further, with the present invention practically negligible wear is created.

Summary of the Invention

In accordance with the present invention, there is provided a stator winding apparatus which includes a reciprocating winding element carrying a supply of material to be wound onto the stator, the winding element being adapted to move at least longitudinally along a first direction. A stationary ring member having an inner circular track defined along the inner circumference of the ring member is also provided, the ring member being adapted to be mounted stationarily with respect to the stator, and a rotatable member having a circular track engaging portion is provided which is mounted for rolling movement along the inner circular track. The track engaging portion of the rotatable member has a diameter which is substantially one-half the diameter of the inner circular track. Moving means are provided for rollingly moving the track engaging portion of the rotatable member along the inner circular track, and connecting means are provided for connecting the rotatable member to the winding element. The connecting means is connected to the rotatable member so as to be pivotable about an axis in alignment with a point on the periphery of the circular track engaging portion, and connected to the winding element so that the winding element is caused to reciprocate along the first direction by the connecting means in response to rolling movement of the track engaging portion along the inner circular track. In this manner, longitudinal or reciprocating motion

of the winding element is produced as the rotatable member rollingly moves about the circular track on the stationary ring member.

In accordance with the preferred embodiment of the present invention, an adjustment mechanism is also provided for adjusting the amplitude or stroke of the reciprocating motion of the winding element. The adjustment mechanism includes means for pivotably mounting the connecting means so as to be pivotable about a pivot point intermediate the ends thereof which are connected to the rotatable member and the winding element, and means for adjusting the position of the pivot point relative to the ring member in a direction generally perpendicular to the axis of pivoting motion. In this manner, the stroke of the reciprocating motion of the winding element will be dependent upon the distance between the ring member and the pivot point of the connecting means, and on the distance between the pivot point and the winding element. Preferably, the connecting means is pivotably carried by a shoe member and the shoe member is movable in a direction transverse to the axis of the pivoting motion to thereby adjust the location of the pivot point relative to the stationary ring member. More preferably adjustment of the shoe member may be accomplished even during operation of the winding apparatus.

These and further features and characteristics of the present invention will be apparent from the following detailed description in which reference is made to the enclosed drawings which illustrate preferred embodiments of the present invention.

Brief Description of the Drawings

Figure 1 illustrates, in perspective, a traditional working diagram of a wire guide device and its movement relative to a stator.

Figures 2a and 2b illustrate a kinematic diagram of the device in accordance with the present invention for controlling the longitudinal movement of a wire guide device.

Figure 3 illustrates schematically the winding apparatus in accordance with the present invention, and also illustrates a mechanism for adjustment of the amplitude of the longitudinal stroke imparted to the wire guide device.

Figure 4 is a side sectional view of a stator winding apparatus in accordance with the present invention, illustrating a possible realization of the schematic illustration of the device shown in Figure 3.

Detailed Description of the Preferred Embodiment

Referring now to the drawings wherein like reference numerals are used to represent like elements, there is illustrated in Figure 1 a conventional stator 10 which may be formed from a plurality of core plates 11 having a constant predetermined profiled and which are arranged in a laminate stack having an axial dimension D. It will be appreciated that the axial or longitudinal dimension of the stator 10 can be modified, within certain limits, by variation of the number of core plates 11 used to form the stack. The stator 10 illustrated in Figure 1 includes two internal field poles 12a, 12b on each of which a winding of electrical conductor or wire is to be formed. The field poles 12a, 12b extend or run in the longitudinal direction, i.e., a direction which will be parallel to the axis of the motor shaft or armature to be placed within the stator 10. Although the stator 10 shown in Figure 1 comprises a bipolar stator (i.e., one having two internal field poles 12a, 12b), it should be appreciated that winding apparatus of the present invention could also be utilized with respect to other types of stators having a greater number of internal field poles by making suitable modifications known in the art.

As is conventional, the winding of the electrical conductors about the internal field poles 12a, 12b, is accomplished with a wire guide device 14 which comprises, for example, a tubular rod 16 carrying a winding head 18 at one end having a pair of radial guide tubes 20 from which wires 22 for forming the windings about each of the internal field poles 12a, 12b may be delivered. The wires 22 are supplied to the tubular rod 16 from a suitable source (not shown) and are then guided to and through the radial guide tubes 20, as is well known. The wire guide device 14 is arranged so that the tubular rod 16 extends in a generally axial direction parallel to the axis of the stator 10.

In order to accomplish the windings of the electrical conductors or wires about the internal field poles 12a, 12b, the wire guide device 14 must be capable of being operated so as to possess both an alternating longitudinal or reciprocal motion, indicated by the double arrow as F_L along the axis of the tubular rod 16, and an alternating angular movement or oscillation indicated by the double arrow F_A. More particularly, in order to wind wires 22 about the field poles 12a, 12b, the wire guide device 14 is initially angularly oriented so that the wires 22 issuing from each of the guide tubes 20 will be directed along the diametrically opposite sides of the respective field poles, e.g. to direct the wires 22 toward the slots 13a, 13c. The guide device 14 is then moved through the central opening of the stator 10 until the radial guide tubes 20 extend beyond the forward face of the stator 10, thereby laying wire in the respective slots 13a, 13c. The wire guide device 14 is then rotated angularly so that the wires or conductors 22 issuing from each of the guide tubes 20 loop over the forward ends of the respective field poles 12a, 12b and so that the guide tubes 20 will be oriented so as to direct the wires 20 along the opposite sides of the respective field poles, e.g. toward the slots 13b, 13d. Thereafter, the guide device 14 is retracted or moved longitudinally rearward until the guide tubes 20 exit from the rear face of the stator 10. During this operation the wires 20 will be laid along the opposite sides of the respective field poles in the diametrically opposite slots 13b, 13d. The guide device 14 is then rotated in the opposite direction so that the wires 22 issuing from the radial guide tubes 20 loop over the

opposite ends of the respective field poles 12a, 12b to form loops of wire along the rearward face of each of the internal field poles 12a, 12b. The wire guide device 14 is then moved forwardly to extend the radial guide tubes 20 beyond the forward face of the stator 10 to direct the wires 22 into the slots 13a, 13c. The guide device 14 is then angularly rotated again so as to form loops along the forward faces of the field poles 12a, 12b and then retracted, etc. These operations are repeated until the formation of windings on the respective internal field poles 12a, 12b is completed.

Thus, it will be appreciated that substantially rectangular paths of movement are provided for each of the wires 22 during the formation of the windings on each of the internal field poles 12a, 12b, and that this rectangular path of movement is obtained by sequentially applying a rotary motion or oscillation and a reciprocating linear motion to the winding head 18. It will further be appreciated that the amount of angular or rotary motion is dependent on the lateral width of the ends of the field poles 12a, 12b, while the longitudinal motion of the wire guide device 14 is dependent on the axial dimension D of the stator 10. Still further, it will be appreciated that in order to provide a high speed winding operation, is is desirable that the longitudinal movement of the wire guide device 14 be slowed down at the ends of its reciprocating strokes so as to permit the wires to be looped over the ends of the field poles 12a, 12b during the angular rotation of the radial guide tubes 20. In other words, it is preferable that a slight dwell time be provided at the ends of the reciprocating strokes during which the wire guide device 14 is rotated in order to thereby provide for an efficient winding operation.

As noted above, various systems are known for controlling the reciprocating or longitudinal movement of the wire guide device 14 with respect to the stator 10, such as for example systems which utilize a connecting rod/crack device for controlling a slider and/or a crank and slotted link device. However, with these known systems, difficulties are encountered which limit the effectiveness and efficiency of the winding operation. For example, difficulties are encountered with the known systems in terms of providing for adjustment of the alternating stroke as well as in connection with providing an efficient balancing of the components in view of the considerable dimensions and weights utilized in the known systems. Still further, with at least some of the known systems, the reciprocating motion is not controlled in a sinusoidal manner, such that synchronism with the angular or rotary motion is difficult. These problems however are overcome with the present invention which provides an apparatus for controlling the linear motion of the wire guide device 14 in a manner such that the rate of movement thereof varies as a sinusoidal function of time, while at the same time providing for the possibility of a highly efficient balancing of the weight and movement, and the possibility of easily carrying out adjustment of the stroke of the reciprocating motion even while the winding apparatus is in operation. Still further, with the present invention alternating sliding movements of the various components is minimized, thereby providing for a practically negligible wear on the various components.

Referring now to Figures 2a and 2b which illustrate the fundamental kinematics of the mechanism for controlling the longitudinal movement of the wire guide device 14, it is seen that there is provided a stationarily mounted ring member 24 having an innner circular track 26 defined along the inner circumference thereof, and a rotatable member 28 having a track engaging portion which is adapted for rolling movement along the inner circular track 26 of the stationary ring 24. In the preferred embodiment, the ring member 24 includes an internal toothed track 26, and the rotatable member comprises a toothed wheel 28 having teeth 30 which engage the internal teeth on the stationary track 26 as the toothed wheel 28 is rollingly moved therealong. The diameter of the toothed wheel 28 is substantially one-half the diameter of the pitch circle of the stationary toothed track 26. Rolling movement of the toothed wheel 28 along the internal toothed track 26 is controlled by means of a connecting link or crank device 32 which serves to interconnect the center or axis 34 of the rotatable toothed wheel 28 and the center or axis 36 of the stationary track 26. The toothed wheel 28 is connected to the crank or link device 32 in a manner to allow it to rotate freely thereon, and the crank or link device 32 is adapted to be rotated about the axis 36 of the circular track 26 at a substantially constant angular velocity. Thus, it will be appreciated that as the crank device 32 is rotated about the axis 36 of the circular track 26, the toothed wheel 28 will rollingly move along the circular track 26. In this regard, the center 34 of the toothed wheel 28 will thus describe a circular trajectory 38 about the center 36 of the circular track 26, the diameter of the trajectory 38 being equal to one-half that of the pitched circle of the toothed track 26.

As best seen in Figures 2a and 2b, as the toothed wheel 28 rollingly moves about the circular track 26, a point P on the periphery of the toothed wheel 28 will describe a straight trajectory 40 which defines a diameter of the circular track 26. If the peripheral point P is chosen to coincide with a point on the circular track 26 when the toothed wheel 28 is at the position shown in Figure 2b, the straight trajectory 40 defined by the point P will comprise the horizontal diameter of the circular track 26. Further, the timing of the movement of the point P is sinusoidal as the toothed wheel 28 moves along the circular track 26, i.e., as the toothed wheel 28 rotates at a constant angular velocity, the rate of movement of the point P will be greatest as the point P passes through the center 36 of the stationary circular track 26, and will approach zero as it reaches the opposite ends of the horizontal

diameter 40. Thus, it will be appreciated that in moving from one end of the horizontal diameter 40 to the other end, the speed at which the point P moves will be a sinusoidal function of time.

In accordance with the present invention, the movement for controlling the reciprocating motion of the wire guide device 14 is taken from the materialization of the point P. More particularly, a connecting member or arm 42 is provided for connecting the rotatable member or wheel 28 to the wire guide device 14, the connecting arm 42 being pivotally connected at one end to the toothed wheel 28 so that it is pivotable about an axis which is in alignment with the point P, and connected at the other end to the wire guide device 14 to thereby control movement of the wire guide device 14 as the rotatable wheel 28 is rollingly moved about the circular track 26.

When no adjustment of the stroke or length of the reciprocating movement of the wire guide device 14 is desired, the movement of the point P may be directly coupled or transmitted to a shoe or other device for controlling or commanding of the wire guide device 14. When adjustment of the stroke is desired, a device such as shown schematically in Figure 3 may be provided in which the connecting means comprises a connecting arm or lever 42 pivotably connected at its ends to the rotatable toothed wheel 28 and to a shoe 44 for controlling longitudinal movement of the tubular shaft 16 of the wire guide device 14, the connecting arm 42 being articulated at a fulcrum point 46 intermediate the ends thereof. The shoe 44 is guided by guides 56 which serve to confine movement of the wire guide device 14 in a generally longitudinal direction. As shown in Figure 3, this longitudinal direction is horizontal. Also, the shoe 44 is such as to permit rotary motion or oscillation of the winding head 18 of the guide device 14 about the longitudinal axis of guide device 14. At one end, the connecting arm 42 includes a longitudinal fork or slot 48 in which a pin 50P is engaged and slides, the pin 50P comprising the materialization of the point P on the periphery of the toothed wheel 28. The other end of the connecting arm 42 includes a second fork or slot 52 which engages a pin 54 on the sliding shoe 44 which controls longitudinal movement of the shaft 16 of the wire guide device 14. The rotatable toothed wheel 28 and the shoe 44 are thus each articulated relative to the arm 42.

It will be appreciated from Figure 3 that as the pin 50P is moved linearly along the horizontal diameter 40 of the toothed track 26, the arm 42 will articulate or pivot about its fulcrum 46 with the pins 50P and 54 sliding in their respective slots or forks 48, 52 for very limited vertical excursions, the amplitude of the excursions being represented by the geometric arrows F_1 and f_2 shown in Figure 3. Obviously, the length of the respective forks or slots 48, 52 is chosen so that the respective pins or 50P and 54 will always remain within the slotted ends 48, 51 of the connecting arm 42.

Also, as the pin 50P moves along the horizontal diameter 40, the pin 54 will move in a horizontal but opposite direction as controlled by the guides 56 for the shoe 44. The amount of longitudinal movement of the shoe 44 (and thus the wire guide device 14) is dependent upon the relative distances that the fulcrum 46 is from the paths of movement of the toothed wheel 28 and the wire guide device 14.

More particularly, the amplitude of the stroke of the shoe 44 (which controls the movement of the wire guide device 14) varies with respect to the amplitude of the stroke of the pin 50P (i.e., the diameter of the pitch circle of track 26), as a function of the ratio of the lengths of the arm portions of the connecting arm 42 connected to the toothed wheel 28 and the wire guide device 14. For example, if the distance or length of the arm portion from the fulcrum 46 to the pin 50P is made longer (by adjustment of the location of the fulcrum point 46 along the length of the connecting arm 42), the amplitude of the stroke of the shoe 44 will be shortened, whereas if the length of the arm portion from the fulcrum 46 to the pin 50P is shortened, the length of the stroke of the shoe 44 will lengthened. It should also be noted that the end points of the reciprocating movement of the wire guide device 14 are defined or occur at the ends of the diameter 40 defined by the pin 50P, i.e., the forward extent of the reciprocating motion occurs when the pin 50P is at one end of the diameter 40 and the rearward extent of the movement occurs when the pin 50P is at the other end of the diameter 40. Accordingly, it will be appreciated that the amplitude of the longitudinal stroke of the shaft 16 of the wire guide device 14 can be controlled by controlling the relative length of the two arm portions of the connecting arm device 42.

In order to carry out this adjustment, there is provided a sliding shoe 58 which carries the fulcrum or pivot point 46 and a sliding guide 60 for guiding movement of the shoe 58 along a desired direction. The position of the sliding shoe 58 within the guide 60 is then adjusted in order to obtain the desired stroke amplitude of the wire guide device 14. This may be accomplished, for example, by means of a pressure screw 62 which may be set to engage the shoe 58 at right angles to the sliding movement permitted by the guide 60. Preferably, the fulcrum point 46 of the connecting arm is adapted to be moved in a direction which is at right angles to the alternating trajectories of the points 28P and the shoe 44 so that the presence of the forks or slots 48 and 52 may be exploited. That, is the fulcrum 46 is preferably moved in a direction which is perpendicular to the axis of the articulating motion of the arm 42. It will thus be appreciated that the amplitude of the stroke of the shoe 44 may be shortened by sliding the shoe 58 downwardly in the embodiment shown in Figure 3, and may be lengthened by sliding the shoe 58 upwardly relative to the guide 60. In this regard, the longitudinal length of the slots 48 and 52 is

preferably sufficient to permit the desired degree of upward and downward movement of the shoe 58, which carries the fulcrum joint 46 of the connecting arm 212.

It will also be appreciated that adjustment of the amplitude of the sliding movement of the shoe 44 in its respective guide 56 (and thus the amplitude of the stroke of the wire guide device 14) can be accomplished even during operation of the device by loosening of the set screw 62 and sliding of the shoe 58 relative to its guide 60. This provides a most advantageous feature of the apparatus in accordance with the present invention so as to permit adjustment of the longitudinal movement of the wire guide device 14 in a relatively simple and quick manner without the necessity of having to stop operation of the winding device. At the same time, since the movement of the pin 50P is controlled as a sinusoidal function of time, as the pin 50P approaches the ends of the horizontal diameter 40 of the track 26 the rate of movement will slow down to in effect provide a dwell time at the opposites ends of the prescribed diameter 40. In this manner, the angular or rotary motion of the wire guide device 14 may be synchronized to occur at the ends of the stroke of the wire guide device 14, i.e., when the radial guide tubes 20 extend beyond the forward end of the stator 10 or behind the rearward end or face of the stator 10. In this regard, it is preferable that the shaft 16 is carried by the shoe 44 so as to permit rotational movement thereof in a manner known per se.

Figure 4 illustrates a preferred arrangement for the stator winding apparatus 70 in accordance with the kinematic representation illustrated in Figure 3, the same reference numerals, where applicable, being utilized. In this regard, the difference between the device 70 illustrated in Figure 4 and that schematically illustrated in Figure 3 include the provision of means for balancing the mass of the toothed wheel 28 to provide for an efficient mass balancing of the apparatus or device 70, and a slightly different arrangement for the regulation or control of the movement of the shoe 58 carrying the articulated joint or fulcrum 46 of the connecting arm 42. More particularly, the winding apparatus 70 as illustrated in Figure 4 includes a rotatable shaft 72 suitably driven by a motor or other device for rotation about the axis of a stationary ring 24 secured to a suitable support member 74 carried by the housing 76 of the winding apparatus 70. The shaft 72 is suitably supported by means of bearings 78 from the housing 76. The end of the shaft 72 carries a symmetric crank element 32a to which a rotatable toothed wheel 28 is mounted at one end and which has a counterweight 80 secured at the other end thereof at the same distance from the axis 36 of rotation of the shaft 72. The toothed wheel 28 is designed to be freely rotatable relative to the symmetrical crank 32a and in this regard is mounted in suitable bearings 82 for rotation about the axis 34 of the wheel 28. The rotatable wheel 28 is mounted to the symmetrical crank 32a in a position so that the outer toothed surface 30 thereof engages the internal toothed surface of the track 26. The counterweight 80 is carried by the symmetrical crank 32a at a diametrically opposite location from the axis 34 of the rotatable wheel 28 and is generally of the same mass as the wheel 28 in order to provide for an efficient balancing of the mass as the shaft 72 is rotated. A protruding pin 50P is provided in alignment with the periphery of the toothed wheel 28 and extends forwardly therefrom. The pin 50P is arranged in a slot 48 at one ends of a connecting arm 42. The connecting arm 42 carries a longitudinally extending shaft 46a mounted in suitable bearings 84 at a point intermediate the ends thereof. The opposite ends of the connecting arm 42 is also provided with a slot or fork 52 in which a pin 54 is adapted to slide. The pin 54 is provided on the outside of a shoe 44 which carries the shaft 16 of the guide device 14 in a manner so as to permit rotational movement of the shaft 16 relative to thereto. The shoe 44 is guided for longitudinal movement by guides 56. Thus, the pin 54 may move within the slot 52 at the end of the connecting arm 42, and the shoe 44 may slide in the guides 56.

The shaft 46a for articulation of the connecting arm 42 is mounted in a shoe or post 58 which in turn is carried by a threaded shaft 86 extending perpendicular from the axis of the shaft 46a. The shoe 58 is adapted to slidably move in a guide 60 which extends in a direction generally perpendicular to the axis of the shaft 46a, the movement of the shoe 58 being controlled by movement of the shaft 86. The shaft 86 is integral with the shoe 58 but is free to rotate with respect thereto so that the shoe 58 may be moved parallel to the guide 60. Longitudinal movement of the shaft 86 is provided by means of a knob 88 which is screw coupled with a threaded bushing 90 engaged in the housing 76 of the device 70. Thus, it will be appreciated that from outside the housing 76, the knob 88 may be rotated to move the shaft 86, and thus the shoe 58, upwardly and downwardly. This turn serves to move the location of the shaft 46a upwardly and downwardly relative to the elevation of the pin 50P and the shaft 16 of the wire guide device 14. It is important to note that adjustment of the position of the shoe 58, and therefore that of the shaft 46a, utilizing the knob 88, may be accomplished even while the device 70 is in operation so that simultaneous reduction of one and extension of the other portions of the connecting arm 42 may be achieved rapidly to obtain a rapid variation of the longitudinal stroke of the wire guide device 14.

It should thus be appreciated that the winding apparatus 70 in accordance with the present invention offers considerable advantages over prior art winding apparatus. In particular, linear motion of the wire guide device 14 may be controlled as a sinusoidal function of time by simply rolling the wheel 28 along the circular track 26 of the stationary ring 24. Since rotation of the

shaft 72 is utilized as the driving force for accomplishing this rolling movement, and thus for controlling the reciprocating longitudinal movement, the force may be readily balanced in accordance with known principles. Further, it is possible to adjust the amplitude of the reciprocating stroke of the wire guide device 14 in a simple manner, even while the device 70 is in operation. Further, the reciprocating motion of the wire guide device 14 as a sinusoidal function of time is most advantageous in terms of synchronization of the angular or rotary motion of the wire guide device. Further, since the alternating motion of wire guide device is synchronous with and in a direction opposite to the alternating motion of the shoe 50P, it is possible to achieve substantial balancing of the respective masses, particularly in a direction parallel to the longitudinal direction of movement of the winding head 18. Furthermore, it should be appreciated that those parts in which relative sliding motion is provided, i.e., the pins 50P, 54 which slide in the forks or slots 48, 57, will have very low sliding speeds, and therefore limited friction and wear will be created which in turn will enhance the life of the device 70.

Thus in accordance with the present invention there is provided an improved winding apparatus for stators and the like in which there is provided a reciprocating winding element 14 carrying a supply of material to be wound on the stator 10, the winding element 14 being adapted to move longitudinally along a first direction. A stationary ring member 24 having an inner circular track 26 defined along the inner circumference thereof is provided which is adapted to be mounted stationarily with respect to the stator 10. A rotatable member 28 having a circular track engaging portion is mounted for rolling movement along the inner circular track 26, the track engaging portion having a diameter which is substantially one-half the diameter of the inner circular track 26. Moving means 32, 72 are provided for rollingly moving the track engaging portion of the rotatable member 28 along the inner circular track 26, and connecting means 42 are provided for connecting the rotatable member 28 to the winding element 14. The connecting means 42 is pivotally connected to the rotatable member 28 so as to be pivotable about an axis which is in alignment with a peripheral point P, 30P on the periphery of the circular track engaging portion on the rotatable member 28, and connected to the winding element 14 so that the winding element 14 will be caused to reciprocate along the first direction by the connecting means 42 in response to rolling movement of the track engaging portion along the inner circular track 26. In accordance with the preferred embodiment, the connecting means 42 is articulated a point 46 intermediate the rotatable member 28 and the winding element 14, and means are provided for adjustment of the position of the articulated joint 46 relative to the ring member 24 and the winding element 14 to thereby provide adjustment of the amplitude of the reciprocating motion imparted to the winding element 14.

While the preferred embodiments of the present invention has been shown and described, it will be understood that such are merely illustrative and that changes may be made without departing from the scope of the invention as claimed.

CLAIMS

1. A stator winding apparatus, comprising:

a reciprocating winding element carrying a supply of material to be wound onto a stator, said winding element being adapted to move longitudinally along a first direction;

a stationary ring member having an inner circular track defined along the inner circumference of said ring member, said ring member being adapted to be mounted stationarily with respect to the stator;

a rotatable member having a circular track engaging portion mounted for rolling movement along said inner circular track, said track engaging portion having a diameter which is substantially one-half the diameter of said inner circular track;

moving means for rollingly moving said track engaging portion of said rotatable member along said inner circular track; and

connecting means for connecting said rotatable member to said winding element, said connecting means being connected to said rotatable member so as to be pivotable with respect to said rotatable member about an axis in alignment with a peripheral point on the periphery of said circular track engaging portion and connected to said winding element so that said winding element is caused to reciprocate along said first direction by said connecting means in response to rolling movement of said track engaging portion along said inner circular track.

2. The stator winding apparatus of Claim 1 wherein said peripheral point on the periphery of said track engaging portion defines a diameter of said circular track as said track engaging portion is rollingly moved about said circular track, the opposite ends of said diameter of said circular track defining first and second diametrically opposite points on said circular track.

3. The stator winding apparatus of Claim 2 wherein said winding element is reciprocated between a first position and a second position along said first direction, and wherein said winding element is in said first position when said peripheral point on said track engaging portion is at said first diametrically opposite point on said circular track and said winding element is in said second position when said peripheral point is at said second diametrically opposite point on said circular track.

4. The stator winding apparatus of Claim 3 wherein said connecting means is connected to said rotatable member such that said diameter of said circular track defined by said peripheral point is parallel to said first direction.

5. The stator winding apparatus of Claim 3

wherein said connecting means comprises a connecting arm extending between said rotatable member and said winding element and first coupling means pivotably coupling a first end of said connecting arm to said rotatable member and said coupling means coupling a second end of said connecting arm to said winding element.

6. The stator winding apparatus of Claim 5 wherein said first coupling means comprises a pin member carried by said rotatable member and a slotted section of said connecting arm in which said pin member is received.

7. The stator winding apparatus of Claim 5 further including adjustment means for adjusting the amplitude of movement of said winding element between said first and second positions, said adjustment means comprising pivot mounting means for pivotally mounting said connecting arm so as to be pivotable about a pivot point intermediate said first and second ends of said connecting arm and adjusting means for adjusting the location of said pivot point relative to said ring member.

8. The stator winding apparatus of Claim 7 wherein said pivot mounting means comprises a shoe member pivotably carrying said connecting arm, and wherein said adjusting means comprises guide means for guiding said shoe member for movement in a direction perpendicular to the axis of said pivot point and means for moving said shoe member relative to said guide means.

9. The stator winding apparatus of Claim 8 further including a housing in which said ring member is stationarily mounted, and wherein said means for moving said shoe member comprises a threaded member rotatably coupled to said shoe member and means for rotating said threaded member to thereby move said shoe member, said means for rotating said threaded member being accessible from outside said housing.

10. The stator winding apparatus of Claim 8 wherein said connecting means further includes winding element mounting means for mounting said winding element for movement along said first direction.

11. The stator winding apparatus of Claim 10 wherein said winding element mounting means comprises means for slidably mounting said winding element for sliding movement along said first direction.

12. The stator winding apparatus of Claim 11 wherein said second coupling means comprises a pin and slot interconnection between said connecting arm and said winding element.

13. The stator winding apparatus of Claim 11 wherein said winding element mounting means further includes means for mounting said winding element to permit rotation of said winding element about an axis extending in said first direction.

14. The stator winding apparatus of Claim 1 wherein moving means comprises a connecting link to which said rotatable member is mounted for rotation about an axis passing through the center of said track engaging portion, and means for rotating said connecting link about an axis passing through the center of said circular track to thereby cause said track engaging portion of said rotatable member to rollingly move along said inner circular track.

15. The stator winding apparatus of Claim 14 further including a counterweight for balancing the mass of said rotatable member, said counterweight being carried by said connecting link and positioned with respect to such axis passing through the center of said circular track diametrically opposite from said rotatable member.

16. The stator winding apparatus of Claim 1 wherein said circular track has a plurality of track teeth along the circumference thereof and said track engaging portion has a plurality of corresponding teeth along the circumference thereof which are engageable with said track teeth as said track engaging portion rollingly moves along said circular track.

17. Apparatus for winding a coil on a core comprising a winding element adapted for reciprocating motion and carrying a supply of coil forming material, means for connecting said winding element to a point on the periphery of a rolling member which rolls around a circular track having a diameter substantially twice that of the rolling member so that said peripheral point reciprocates along a straight line.

18. A winding apparatus substantially as herein described with reference to Figures 2 to 4 of the accompanying drawings.

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